AC 2010-94: PREVIEW, EXERCISE, TEACHING AND LEARNING IN DIGITAL ELECTRONICS EDUCATION

Guoping Wang, Indiana University-Purdue University, Fort Wayne

Active Learning in Digital Electronics: Preview, Exercise, Teaching and Learning

Abstract

Through multimedia delivery of new materials, web-based warm-up exercises and interactive classroom teaching/learning, this paper presents a new teaching approach - PETL (Preview, Exercise, Teaching and Learning) in teaching and learning digital electronics. Different from the traditional recitation-based lecture formats, the proposed pedagogy is a teaching and learning strategy based on the active participation of learners at each stage of the learning process, namely, preview of new topics, web-based warm-up assignments, and interactive classroom teaching and learning. Students briefly preview the new materials delivered through web-based multimedia, and then respond electronically to carefully constructed warm-up exercises which are due before class. The instructor reviews students' responses and adjusts the classroom lesson based on students' concerns and questions. The preview materials, with the instructor's explanations added, are produced using Flash multimedia authoring tool. This provides an on-line learning tool to prepare the students for the warm-up exercises. Anonymous surveys, questionnaires before, in the middle and after the implementation of the project are conducted to assess the effectiveness and outcomes of this project. Samples of the warm-up questions, the implementation and assessment plan of the PETL are described in the paper. In the end, a summary concludes that the proposed method shows effective in the teaching and learning of digital electronics course at IPFW.

Keywords: Active Learning, Multimedia Delivery, WebCT, JiTT.

1. Introduction

In a traditional classroom, students are passive listeners most of the time. They come to the classroom unprepared and just listen to the instructor and take notes. This classroom environment lacks interactions between faculty and students, and between students themselves. These interactions are very important to the academic success of the students. If students actively participate in the classroom learning activities, they will be more cognitively engaged and as a result be able to achieve a better understanding of new materials.

Through multimedia delivery of new materials, web-based warm-up exercises and interactive classroom teaching/learning, this paper presents an effective approach – PETL (Preview, Exercise, Teaching and Learning) in teaching and learning digital electronics. This pedagogy is based on the active participation of learners at each stage of the learning process, namely, preview of new topics, web-based warm-up assignments, and interactive classroom teaching and learning. Students briefly preview the new materials delivered through web-based multimedia, and then respond electronically to carefully constructed warm-up exercises which are due before class. The instructor reviews students' responses and adjusts the classroom lesson based on students' concerns and questions. The interactive classroom session, built around these responses, replaces the traditional lecture/recitation format. In general, PETL strategy pursues three major goals:

1. To maximize the effectiveness of the classroom session.

2. To structure the out-of-class time for maximum learning benefit.
3. To create and sustain team spirit. Students and instructors work as a team toward the same objective ─ to help all students master course contents with the maximum amount of retainable and transferable knowledge.

Here is how PETL format differs from the traditional teaching format. In a traditional teaching environment (see Figure 1), the instructor comes to the classroom with prepared lecture notes. Students are passive information receivers without knowledge of what will be taught. In a PETL teaching classroom (see Figure 2), the instructor adjusts lecture contents based on students' responses to warm-up assignments and comes to the classroom with proper knowledge of students' questions and concerns. Students will be more attentive in class because the lecture contents are adjusted to their level of understanding and students' concerns are addressed through properly designed classroom discussions.

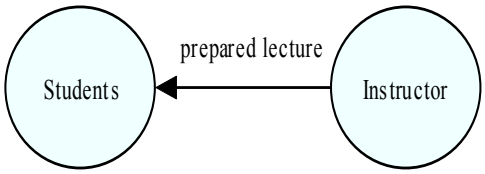

Figure 1. The Traditional Teaching Environment

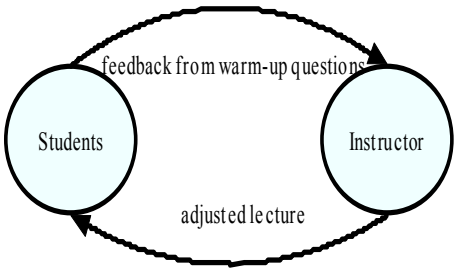

Figure 2. PETL Teaching Environment

2. Previous Research

Multimedia: Multimedia includes a combination of text, graphics, sound, video, and animation sequences, etc. to form an interactive visual/audio presentation of information and knowledge. Interactive multimedia can be used to support education and training, to serve as a reference tool and to provide dynamic presentations [1,2]. Educational research has showed that if information is conveyed to the students in a combination of text, color, graphics, animation, sound, moving pictures, and a degree of interactivity, the interactive multimedia approach may result in a significant increase in retention, improvement in the learning rate and active learning process[3-5]. According to Stoney and Oliver's report, "The use of interactive multimedia can foster and develop cognitive engagement through its ability to attract and hold students' attention and focus."[6]

WebCT: WebCT technology has been used by educators at more than 2000 colleges and universities in more than 70 countries[7]. The latest version of WebCT – Blackboard is a Web-based course-

management system designed to allow students and faculty to participate in classes delivered online or use online materials and activities to complement face-to-face teaching. It is a Virtual Learning Environment that supports online learning and teaching. It can be accessed by registered users from anywhere in the world using the Internet and web browsers.

Just-in-Time-Teaching: JiTT – a web-based learning and teaching strategy was pioneered as a collaborative effort of physics faculty at the United States Air Force Academy and Indiana University-Purdue University Indianapolis. It is a feedback-intensive teaching and learning strategy [8,9]. In a typical implementation, students respond electronically to carefully constructed warm-up assignments due before class, and the instructor reviews the answers and adjusts the classroom lesson to meet student needs.

In most engineering subjects, without prior knowledge of new materials, it is very difficult to do any warm-up exercises and have a good discussion of the engineering new concepts. Thus, it is almost impossible to apply JiTT to the instructional activities of engineering without significant modifications.

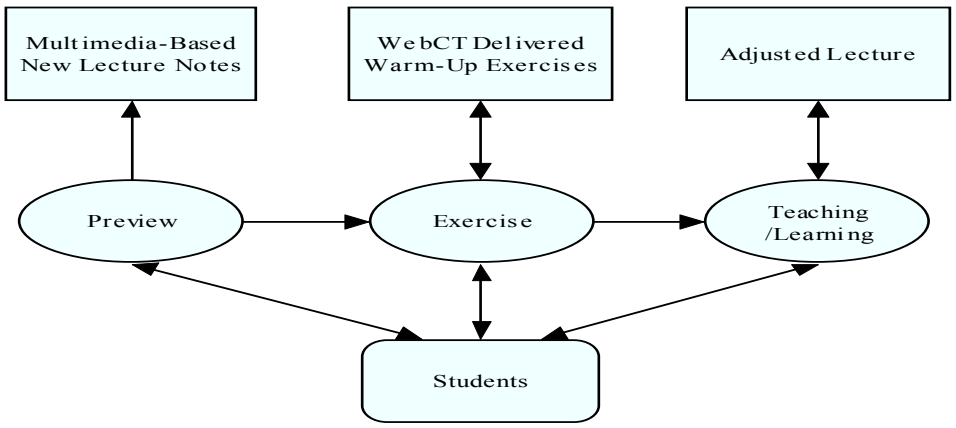

Figure 3. PETL Instructional Model

Based upon the research and teaching results of JiTT, a new pedagogical approach – PETL is proposed in this project. It consists of multimedia delivery of new materials, web-based warm-up exercises and interactive classroom teaching/learning. The web is used to generate interactivity with the students, deliver preview materials, have students go over preparatory assignments, or simple essay questions shortly before the lecture session. PETL assists learning engineering concepts before the lecture, with the pedagogical strategy known as "active learning" or "interactive engagement" [10], in the subsequent classroom session that is tailored to students' needs. Figure 3 shows the PETL pedagogical model, in which students are the center of these learning activities.

3. Implementation

The Proposed PETL methodology takes up most of the design and development effort in this project. It leads to instructional materials focusing on digital circuit principles and practices during the sophomore year, incorporating interactive multimedia, the Web, and instructional strategies that promote active learning and problem-solving skills of undergraduate engineering students.

The following are the intended objectives related to project PETL implementation in this introductory electrical and computer engineering course:

- Improving learning in undergraduate electrical and computer engineering through increased emphasis on students' active learning.
- Developing effective strategies for the integration of interactive multimedia and the Web in electrical and computer engineering instructional activities.
- Fostering changes in the teaching-learning environment during the lecture period.
- Creating a program in electrical and computer engineering that can serve as a resource and model to other engineering subjects nationwide.
- Promoting retention of undergraduate engineering majors, especially for non-traditional, academically at-risk students.

The teaching and learning materials takes the form of Flash-based multimedia preview materials, and on-line warm-up assignments. The materials will cover a standard one-semester course in digital electronics. Widely adopted textbooks from Kleitz [11], Wakerly[12] and Mano[13] are used to design the multimedia preview, including topics in number systems and codes, combinational logic circuits, programmable logic device applications, sequential logic circuits, and timing analysis.

ECE 270 – Introduction to Digital Systems Design is composed of lectures and lab sessions. The lecture is given in two sessions each week for one semester and the subsequent lab sessions are given to help students understand the principles and practices of digital electronics. Each week one session is devoted to PETL learning and teaching practices, in which students spend around 20 minutes to preview the topics of that week through interactive multimedia tutorials and spend another 20 minutes to answer the warm-up exercises delivered through WebCT. The instructor adjusts the classroom teaching contents to address students' concerns and questions based upon the results of the warm-up answers. An average of three Flash-based multimedia tutorials per week has been developed.

One outstanding feature of Flash-based multimedia tutorials is that they are two-way and have an interactive interface for the students. For example, a tutorial to explain the principles and applications of a digital multiplexer would be implemented as a composition of sequential Flash clips:

- Clip one: The concept of digital multiplexer is illustrated. Comparisons between digital and analog switches are made using expert's commentary and interactive multimedia.
- Clip two: A simulation of a multiplexer is shown to let the students better understand the concepts of a multiplexer, in which students can control the data selection signals to pick the corresponding input in the output.
- Clip three: The internal structure of gate connections is drawn. This will help the students to grasp the principles and theories of the multiplexer from inside and outside.

It is challenging to develop the warm-up questions due to the nature of the subject compared to the arts and sciences. In the arts and sciences courses, most of the warm-up questions could be subjective, and thus they could lead to some good discussion during the lecture time. In contrast,

most of the warm-up questions in the engineering field are objective. Thus the development of these questions may require a different approach.

The warm-up questions are based on the categories adapted from a classic article on college science teaching by A.B. Arons[14]. These assignments are introduced to examine students' understanding of new terms and definitions and their ability to explain the meaning of a concept, or a particular jargon, articulate their thinking processes when dealing with difficult ideas, draw inferences from data and evidence, and translate words into written symbols and written symbols into words. The following are some samples of short answer and essay warm-up questions for ECE 270 PETL exercises.

Sample warm-up short answer questions:

1) Introducing the idea of AND, OR operations in Boolean algebra.

Please draw at least two graphs to control a light bulb while using two switches at your home.

2) Introducing different radices.

Please give some examples of number counting in your daily life besides using decimal number system. If you can only use the number 0 and 1, can you think of a way of counting the numbers from 0 to 20?

3) Introducing the new concepts of encoding and decoding in digital logic system.

Think of at least two methods to represent the alphabet letters A,B,C,D,E,F,G,H using binary numbers 0 and 1.

Sample essay warm-up question:

Please represent the alphabet letters A,B,C,D,E,F,G,H using binary numbers. Please explain your answers and answer the following questions.

a) Is it necessary to encode all the letters in the same length of bits? Please explain your answer.
b) Is it necessary to encode all the letters in the binary ascending or descending order? Please explain your answer.

This essay question will be used as a warm-up exercise early in the course after the binary number concept has been introduced. This is an open-ended question with answers that can lead to a good discussion in the classroom. Some possible answers are listed in the following:

1) Binary number representations of letters from A to H as

A-000, B-001, C-010, D-011, E-100, F-101, G-110, H-111

2) ASCII code representations

A- 1000001 (41H), B-1000010 (42H), C-1000011 (43H), D-1000100 (44H), E- 1000101 (45H), F-1000110 (46H), G-1000111 (47H), H-1001000 (48H)

3) 1-out-of-8 representations.

A- 00000001, B-00000010, C-00000100, D-00001000, E- 00010000, F-00100000, G-01000000, H-10000000

4) Other answers.

The above essay question is assigned to the students when the binary number system has just been introduced and students have learned how to represent a decimal number in binary system. The answer to this warm-up question seems very simple and straightforward. Answer one is a direct and straightforward answer. As to answer two, some students may look it up in the textbook and other reference books to find the ASCII encoding. It is also possible that some students may come up with answer three or other answers. Here are some thoughts for the discussion following these answers.

Question 1: Is it necessary to encode all the letters in the same length of bits?

This discussion can lead to the introduction of not-the-same-length encoding. If the probabilities of these letter appearances are different, the encoding bit length may not be the same for each symbol. Assume that the probabilities of the letter appearances are: A-0.25, B-0.2, C-0.175, D-0.125, E-0.1, F-0.975, G-0.0625, H-0.0625, the following encoding will result in the minimum entropy.

A-1, B-01, C-001, D-0001, E-00001,F-000001,G-0000000,H-00000001.

Question 2: Is it necessary to encode all the letters in the binary ascending order?

The encoding of these letters isn't necessarily encoded in binary ascending or descending order. The concept of Gray encoding can be introduced here. Gray encoding is a binary encoding in which only one bit changes between each pair of successive code words. The 3-bit Gray codes are listed as:

A-000, B-001, C-011, D-010, E- 110, F-111, G-101, H-100

The concept of combinational logic circuit encoder and decoder could also be introduced in this discussion. Basically, encoder and decoder perform the code conversions between these different encoding systems. In a decoder, the number of input codes is bigger than that of the outputs. For example, a 3-8 decoder is needed to convert a binary encoding in answer one to 1-out-of-8 encoding in answer three. Vice versa, an 8-to-3 encoder can convert 1-out-of-8 encoding in answer three to a 3-bit binary encoding in answer one.

The ASCII table can also be introduced in the discussion following answer two. The American Standard Code for Information Interchange (ASCII) represents each character with a 7-bit string, yielding a total of 128 different characters. The code contains the uppercase and lowercase alphabet, numerals, punctuation, and various nonprinting control characters. It is the most commonly used character code.

4. Project Assessment Plan

Throughout the project, the PETL teaching/learning activities in Figure 4 are followed.

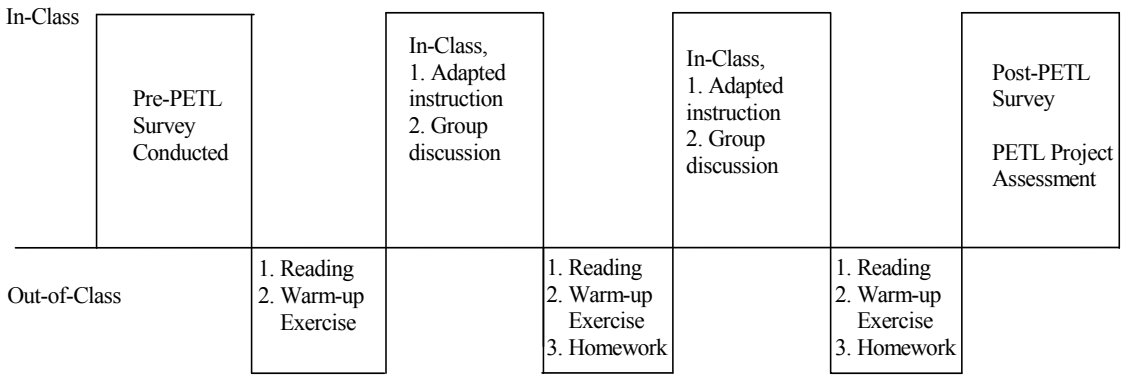

Figure 4. PETL Exercise Activities

Project outcomes, which include students' attitude change, student-instructor's interactions, time spent in and out of class presentations, and the nature of PETL presentations, are assessed and evaluated using surveys/questionnaires. Student responses to a standard attitudinal survey and anonymous end-of-course survey responses are used to generate information regarding students' attitudes and thoughts relevant to this PETL course. Initial assessment results from 2007-2008 academic year suggested that the following goals have been achieved:

- The effectiveness of the classroom session is maximized.
- Out-of-class time is structured for maximum learning benefit.
- Team spirit is created and sustained.
- Students are engaged in the classroom learning and teaching.

5. Summary

A new pedagogy based on Multimedia and world-wide-web delivery of preview module and warm-up exercises, adjusted classroom teaching/learning is presented in this paper. This instructional approach is expected to enhance student learning in the typical digital electronics course. It will encourage students to take an active part in the learning process. For example, the preview materials and warm-up exercises will help students to prepare for learning new contents. The interactive classroom session, built around students' responses to warm-up exercises, replaces the traditional lecture/recitation format. The interactions between the instructor and the students promote active learning, and maximize the effect of the classroom session. The on-line delivery is especially helpful to the learning activities of non-traditional and physically-disabled students, who are underrepresented in the STEM fields.

6. Acknowledgment

Partial support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement (CCLI) program under Award No. 0632686. Any opinions, findings,

and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.

References

[1] A. C. Luther, *Design Interactive Multimedia*. New York: Bantam, 1992.

[2] C. Chen, *HyperSource on Multimedia/Hypermedia Technologies*. Chicago, IL: American Library Association, 1989.

[3] E. Hansen, "The role of interactive video technology in higher education: Case study and proposed framework," *American Library Association*, pp. 13–21, Sept 1990.

[4] D. Myers, "Interactive video: A chance to plug the literary leak," *Industry Week*, no. 239, pp. 15–18, April 1990.

[5] H. J. Bailey and N. E. Thornton, "Interactive video: Innovative episodes for enhancing education," *Computer Applications in Engineering Education*, no. 1, pp. 97–108, 1992-1993.

[6] S. Stoney and R. Oliver, "Can higher order thinking and cognitive engagement be enhanced with multimedia?" *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning*, no. 7, 1999.

[7] Webct. [Online]. Available: http://www.webct.com

[8] G. M. N. et al., *Just-in-Time Teaching: Blending Active Learning with Web Technology*. Upper Saddle River, NJ: Prentice Hall, 1999.

[9] A. Gavrin, K. Marrs, and R. Blake, "Just-in-time teaching JiTT: Using the web to enhance classroom learning," *Computers in education journal*, no. 2, pp. 51–60, 2004.

[10] R. Hake, "Interactive-engagement vs. traditional methods," *American Journal of Physics*, no. 66, pp. 64–74, 1998.

[11] Digital Electronics: A Practical Approach, W. Kleitz, 7th Edition, Prentice Hall, 2005.

[12] Digital Design: Principles and Practices, J. F. Wakerly, 4th Edition, Prentice Hall, 2006.

[13] Digital Design, M. M. Mano, 3rd Edition, Prentice Hall, 2001.

[14] Arons, A. (1979). "Some Thoughts on Reasoning Capacities Implicitly Expected of College Students," *Cognitive Process Instruction: Research on Teaching Thinking Skills*, Jack Lochead and John Clement, Eds. Philadelphia: The Franklin Press.